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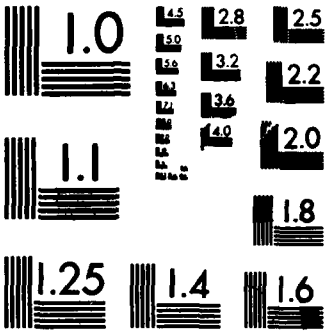

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Psychological Correlates of Cortisol Excretion in Normal Individuals under Stress[†]

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SUMMARY

Psychobiological models of disease assume that psychological factors affect biological status in ways that increase the risk of illness or the severity of illness when it occurs. Cortisol excretion is a possible biological determinant of health outcomes which is believed to be influenced by psychological factors. The belief that cortisol excretion is related to psychological factors in normal individuals has been called into question by several recent reports that psychological variables were not related to cortisol excretion in normal individuals. This study tested the hypothesis that these negative findings were obtained because participants in these studies were not facing a significant acute challenge when studied.

Method The general hypothesis was tested by relating personality, perceived stress, and mood to cortisol excretion in Marine Corps recruits (N = 39) during the first phase of Marine Corps basic training. This period of basic training is acknowledged to be stressful and therefore provided a suitable test of the hypothesis.

Self-reports of the personality dimensions of introversion-extraversion and emotional stability-neuroticism were obtained prior to basic training. Perceived stress and mood state were measured at the beginning of basic training and at the end of the first and second weeks. Cortisol excretion was measured by radioimmunoassay of saliva samples collected at the same time as the stress and mood measures. The repeated measures for mood, perceived stress, and cortisol excretion were averaged to ensure reliable assessment of individual differences. Pearson product moment correlations estimated bivariate associations and multiple regression assessed multivariate associations.

Results Mood scores predicted cortisol excretion better than personality and perceived stress did. Several indicators of negative mood

were significant predictors, but depressed mood was the strongest correlate of cortisol excretion ($r = .38$). None of the associations for perceived stress were statistically significant, but there was a positive association to feeling pressured and overloaded which replicated a previously reported association ($r = .18$, $p < .14$).

Conclusions Cortisol excretion was related significantly to emotional status, but not to perceived stress or personality, under conditions which require significant psychological and behavioral adaptation. The pattern of findings was consistent with models that regard emotion, particularly depression, as a key psychological correlate of biological processes and adaptational challenge as a precondition for demonstrating such correlations. Under these conditions, perceived stress and personality may be important determinants of the type and level of emotional reaction which then affects cortisol excretion. Alternatively, perceived stress may be influenced by emotional states which are responses to cortisol excretion caused by the situation. Further studies to test these interpretations, which are not necessarily mutually exclusive, could help clarify relationships between stress and adverse health outcomes.

INTRODUCTION

Psychobiological models commonly assume that personality, psychological stress, and affective tendencies are psychological contributors to disease. One reason for believing that psychological factors contribute to the development and maintenance of disease is that people demonstrate a wide range of physiological reactions when exposed to objectively similar circumstances (Mason, 1968; 1975). Individual differences in perceived stress, emotion, or personality may mediate these response differences. If so, these psychological attributes should be related to biological mechanisms which can transform psychosocial stresses into physiological processes that lead to illness (Weiner, 1972). Cortisol excretion is a potential link between psychological states and illness because this physiological variable is sensitive to stress (Mason, 1968; 1975) and has a range of physiological effects that may influence physical and mental health (Munck, Guyre, & Holbrook, 1984; Carroll & Mendels, 1976). However, several recent studies have failed to demonstrate associations between cortisol excretion and mood (Jenner, Anderson, & Harrison, 1985), perceived job stress (Caplan, Cobb, & French, 1979), and personality (Ballenger, et al., 1983) in normals. Another study has reported associations for mood and personality which were variable over time in a longitudinal study (Herbert, Moore, de la Riva, & Watts, 1986). The general trend toward negative findings raises doubts about the importance of cortisol as a biological intermediary in processes linking psychosocial stimuli to disease in normal individuals.

The central hypothesis in this study was that the negative findings cited above were obtained because a basic requirement for testing psychobiological models was *not* satisfied. In particular, it is likely that few of the participants in the studies by Caplan, et al. (1979), Ballenger, et al. (1983), and Jenner, et al. (1985) faced significant psychological stresses when studied. Significant stress may be necessary to activate the processes of interest in psychobiological models. Support for this position is provided by evidence from a series of studies of clinical ratings of psychological characteristics labelled "effectiveness of defenses" (Wolff, Friedman, Hofer, & Mason, 1964; Wolff, Hofer, & Mason, 1964). These ratings reliably predict cortisol excretion in normals under stress, but not under everyday conditions (Vickers, 1985). In the Herbert, et al. (1986) study, the stress of impending

scholastic examinations may have been an important determinant of when significant associations occurred.

Specific hypotheses regarding the psychological correlates of cortisol excretion under stress were generalizations from the prior effectiveness of defenses research. This basis for hypotheses was emphasized because effectiveness of defenses research has produced reliable associations between individual differences in psychological attributes and individual differences in cortisol excretion in a number of studies (cf., Vickers, 1985, for a review). The emotion concepts measured by the standardized self-reports of mood used by Jenner, et al. (1985) are similar to those measured by an affective disruption criterion which is one component of effectiveness of defenses ratings. This criterion appears to be the key element in the overall effectiveness of defenses ratings (Katz, Weiner, Gallagher, & Hellman, 1970; Knight, et al., 1979). Therefore, it was predicted that self-reported negative mood would be associated with higher cortisol excretion in normals in a stressful situation. It was further predicted that perceived stress and the personality attributes of introversion and neuroticism would be associated with higher cortisol excretion under stress. This extension of the basic hypothesis was based on established associations between negative moods and stress and personality (Caplan, Cobb, French, Harrison, & Pinneau, 1975; Costa & McCrae, 1980; Diener & Emmons, 1984).

The hypotheses were tested by predicting cortisol excretion in a sample of Marine Corps recruits during basic training from self-report measures of mood, stress, and personality. Basic training is generally acknowledged to require significant adaptation on the part of recruits (Maskin & Altman, 1943; Janis, 1945; Bourne, 1967; Zurcher, 1968) and elicits strong emotional reactions (Datel & Engel, 1966; LaRocco, Ryman, & Biersner, 1977). Therefore, this situation is stressful whether stress is defined by observers evaluating adaptational requirements or by participant consensus if emotional states are regarded as reasonable indicators of stress. A significant association between cortisol and effectiveness of defenses has been demonstrated in basic training (Rose, Poe, & Mason, 1968). This association was particularly pronounced during the initial period of training (Vickers, 1985) when negative affect is highest. Thus, a failure to obtain significant associations in this study would contrast directly with results obtained with clinical ratings of effectiveness of defenses in the same stressful situation.

METHOD

Sample

Marine Corps recruits (N = 39) were selected at random from volunteers for a study of the effects of stress in basic training. The average recruit in this sample was 19.0 (S.D. = 1.4) years of age compared to 19.1 (S.D. = 1.6) for the other volunteers ($t = 0.11$, $p = .915$). The sampled recruits reported fewer years education (11.74 versus 11.94, $t = 1.72$, $p < .086$) and had a lower likelihood of having a high school diploma or graduate equivalency diploma (16% versus 34%, chi-square = 7.51, $p < .007$). The sampled recruits also included a lower proportion of non-whites than the overall volunteers (5% versus 20%, chi-square = 5.03, $p < .026$). However, the sampled recruits did not differ from the other volunteers with respect to personality, perceived stress, or mood during basic training.

Mood

Mood was measured with a 40-item mood questionnaire (Ryman, Biersner, & LaRocco, 1974). Participants indicated for each item how well the term described them that day using a scale from "Not at all" (scored 1) to "Mostly or generally" (scored 3). Scores for anger, activity, depression, fatigue, fear/anxiety, and happiness were computed using the scoring key provided by Ryman, et al. (1974). The general dimensions of positive and negative mood were scored using algorithms developed by Vickers and Hervig (1985). These authors showed that the positive and negative mood dimensions defined by this instrument closely parallel the consensual two-factor mood model identified in many other mood questionnaires (Watson & Tellegen, 1985), so the general positive and negative mood dimensions can be used to test recent two-dimensional models of mood proposed by Russell (1980) and Plutchik (1980). Mood scores were averaged over three days of data collection to provide stable estimates of mood differences in this specific situation.

Introversion and Neuroticism

Abbreviated versions of the factor scales developed by Nichols and Schnell (1963) measured introversion and neuroticism. The full scales are reasonable indicators of these personality constructs (Eysenck, 1981). The abbreviated scales were constructed after factor analyses of 289 California Psychological Inventory items in a sample of 2648 Marine Corps recruits con-

firmed the existence of the Nicholls-Schnell dimensions in this population. The abbreviated scales correlated very highly with the full scales (neuroticism, r = .96; introversion, r = .98) in a sample of 490 middle-aged men.

Perceived Stress

Ten stresses which prior research and interviews with recruits indicated were important in basic training were measured. These stresses included (a) the absence of clearly defined role expectations (Role Ambiguity), (b) the presence of conflicting behavioral demands from different training personnel (Role Conflict), (c) having many things to do relative to the time available and constant pressure to hurry (Pressure), (d) loss of personal freedom (Loss of Autonomy), (e) not being treated with respect as an individual (Loss of Personal Integrity), (f) absence of opportunities for personal development and improvement (Lack of Challenge), (g) being constantly watched for mistakes (Surveillance), (h) being punished unfairly (Punishment), (i) a low assessment of ability to meet the academic, physical, and other demands of basic training (Low Performance Expectancies), and (j) the belief that punishments and rewards depended on the behavior of others rather than one's own performance (Low Performance Instrumentality).

Three to six items were developed to measure each stress as reflected in recruits' descriptions of basic training with response options from "Disagree strongly" (scored 1) to "Agree strongly" (scored 7). Principal factor analyses confirmed eight of the ten stresses as originally defined, but Punishment and Surveillance formed a single factor and were combined into a single scale. The reliability of the scales estimated by Heise's (1969) path analytic procedures ranged from .77 to .96; seven of nine coefficients were greater than .91. Details regarding stress scale development procedures are available from the authors on request.

Cortisol Sampling and Assay Procedures

Saliva was the medium for measuring cortisol excretion because salivary collection procedures were noninvasive, easily applied to large groups of recruits in a field setting, and provide estimates of cortisol excretion that are highly similar to those obtained with serum or plasma values (Walker, 1984). Saliva was collected by having participants deposit whole saliva in a

sterile plastic vial for one minute on the days that subjects completed the mood and stress questionnaires. All samples were collected between 1720 and 1740 to minimize effects of circadian variation in cortisol levels. Samples were placed on ice after collection, then centrifuged, aliquotted and frozen until thawed for assay.

Cortisol concentrations in saliva were determined by the radioimmunoassay procedures of Foster and Dunn (1974). The determinations for the three days were averaged to assess general cortisol excretion trends similar to the pooled urinary measurements employed by Rose, et al. (1970). No adjustment was made for salivary flow rate, because flow rate does not affect cortisol concentrations (Ferguson, 1984; Vining & McGinley, 1984).

Analysis Procedures

A square root transformation was applied to the cortisol excretion values to reduce skewness in the distribution. The transformation was made to improve the approximation of the overall frequency distribution to normality, an assumed condition for the statistical significance tests used, and to reduce the influence of any extreme data points on the analysis results.

Regression analyses assessed the relationship between cortisol excretion and personality, mood, and perceived stress. Residuals analysis (Stevens, 1984) showed that no substantial outliers or influential data points were present. Partial correlations tested whether mood was related to cortisol controlling for stress and whether stress was related to cortisol controlling for mood. Moderated multiple regressions utilizing the cross-product of two predictors to represent possible interactions (Saunders, 1956; Cohen, 1978) tested for interactions in several exploratory analyses. The significance level for the moderated regressions was $p < .10$ to allow for potentially low reliability of cross-products (Bohrnstedt & Marwell, 1978). The significance criterion was applied to the improvement in fit of the overall regression equation when the cross-product was entered after the main effects. This significance test is meaningful as an evaluation of overall predictive accuracy (Cohen, 1978) and avoids the collinearity problems involved in testing for the significance of the regression coefficient for the cross-product (Morris, Sherman, & Mansfield, 1986).

RESULTS

Perceptions of and Emotional Reactions to Basic Training

The psychological status of the average recruit is described in Table 1. On the average, positive affect predominated despite the stressful nature of basic training. For example, the average Active score was higher than the comparable Fatigue score and the average Happiness score was higher than the comparable scores for Anger, Depression, and Fear/Anxiety.

TABLE 1
PSYCHOLOGICAL CORRELATES OF CORTISOL EXCRETION

	MEAN	S.D.	r	SIGNIFICANCE
GENERAL MOOD DIMENSIONS				
NEGATIVE	3.37	0.53	.32	.024
POSITIVE	3.00	0.49	−.18	.131
SPECIFIC MOODS				
ACTIVE	2.10	0.41	−.16	.168
ANGER	1.79	0.42	.27	.046
DEPRESSION	1.55	0.46	.38	.009
FATIGUE	1.81	0.40	.12	.240
FEAR/ANXIETY	1.39	0.36	.34	.016
HAPPINESS	1.88	0.43	−.32	.022
PERSONALITY				
INTROVERSION	0.30	0.18	.10	.269
NEUROTICISM	0.58	0.12	.03	.440
PSYCHOLOGICAL STRESS				
ROLE AMBIGUITY	2.68	0.95	−.01	.532
ROLE CONFLICT	5.50	0.84	.21	.105
PRESSURE	6.16	0.82	.18	.139
LOSS OF AUTONOMY	5.28	1.31	.22	.089
LOSS OF PERSONAL INTEGRITY	4.51	1.36	.16	.172
LACK OF CHALLENGE	3.52	1.12	.05	.374
PUNISHMENT/SURVEILLANCE	4.88	1.07	.15	.175
LOW PERFORMANCE EXPECTANCIES	2.66	0.88	.13	.223
LOW PERFORMANCE INSTRUMENTALITY	4.28	1.34	−.10	.729

NOTE: One-tailed significance tests were used given the hypotheses that high scores on each of the indicated measures except the positive moods would be related to higher cortisol excretion. The hypotheses were reversed for the positive moods.

Role conflict, pressure, and loss of personal autonomy were the most prevalent stresses as the frequency distributions for these scales showed that most recruits agreed these stresses were present. Role ambiguity and low performance expectancies generally were absent. The remaining stress measures had score distributions which indicated that some recruits reported them to be present in mild form and others suggested they were not present.

Psychological Correlates of Cortisol Excretion

Negative affect predicted cortisol excretion, but perceived stress and personality did not (Table 1). Partial correlations between cortisol excretion and the remaining moods controlling for Depression were statistically nonsignificant ($p > .215$).

Moderated multiple regressions were performed to determine whether perceived stress or personality interacted with mood to predict cortisol excretion and whether interactions between the two general mood dimensions predicted cortisol excretion. These analyses produced uniformly nonsignificant results.

DISCUSSION

This study demonstrated that cortisol excretion in normals is related to negative affect, but not to perceived stress or personality, during a period of significant adaptational challenge. Although this study did not directly compare high and low challenge periods, the inference that challenge is important has been drawn for two reasons. This inference can explain the difference between the present positive findings and Jenner, et al.'s (1985) negative findings if it is assumed Jenner, et al.'s (1985) general population sample included few individuals who were facing significant adaptational challenge when studied. This line of reasoning can be extended to Herbert, et al.'s (1986) inconsistent associations between cortisol excretion and affect in a single sample studied over time by assuming the variations arose from differences in the stress levels at different points in their study. The second reason is that an inference about adaptational demands is supported by the qualitative consistency between the present results and those from effectiveness of defenses research. This matching seems appropriate given that effectiveness of defenses includes affective expression as a major

component (Vickers, 1985). Thus, inferring that stressful conditions are required to demonstrate an association between affect and cortisol excretion in normals helps integrate diverse findings in psychobiological research into an interpretable, consistent pattern.

In view of the apparent importance of stressful conditions, it was surprising that perceived stress was not more important as a predictor of cortisol excretion and as a moderator of the affect-cortisol relationship. This finding may be influenced by methodological limitations of the available studies. The findings regarding Pressure suggest that reliable associations between perceived stress and cortisol may exist. This scale was conceptually similar to Caplan, et al.'s (1979) work load measure. The correlation in this study ($r = .18$) was closely comparable to the correlation in their study ($r = .16$). Most participants in the present study reported high pressure while most in Caplan, et al.'s (1979) sample reported low pressure. Thus, both studies involve restricted ranges of stress. In the present case, the restricted range was important because the specific research objective was to examine psychological correlates of cortisol excretion under stress. However, the important point is that available studies leave open the possibility that the association between perceived pressure and cortisol excretion not only is reliable, but would be substantial in any study that covered the full range of stress. This trend may generalize to other stresses, particularly role conflict and loss of autonomy which were comparable to pressure as predictors of cortisol excretion in this study. Overall, the available evidence is inconclusive regarding the magnitude of perceived stress-cortisol associations. Further studies of this topic could be informative, but these studies should consider the possibility that perceived stresses can be viewed as instances of the cognitive precursors of emotion defined in current theoretical models (cf., Smith & Ellsworth, 1985). Given this perspective and the apparently reliable association between affect and cortisol excretion, future studies of perceived stress and cortisol excretion should test the hypothesis that perceived stress is related to cortisol excretion indirectly through its influence on emotional reactions to demanding situations.

Cortisol excretion may be related primarily to depressed mood. This mood was the strongest affective correlate of cortisol excretion in this study and a similar trend has been reported by Herbert, et al. (1986, p. 222). If

this trend proves reliable in further research, it would support the validity of discriminating depression from highly correlated negative affects such as anxiety (Dobson, 1985) and would imply that two-dimensional models of affect (Russell, 1980; Plutchik, 1980; Watson & Tellegen, 1985) are too general to be suitable for understanding relationships between affect and physiology. The latter implication would be consistent with psychobiological models that assume specificity of affect-physiological response associations (e.g., Lazarus & Folkman, 1984). This conclusion must be tentative, because two studies are insufficient to establish the reliability of the observed trend. Katz, et al. (1970) and Knight, et al. (1979) provide additional evidence that cortisol excretion in normals is related to overall negative affect under stressful conditions, but their findings did not consider the predictive value of specific affects. Thus, a moderately strong relationship between negative affect and cortisol excretion in normals facing significant real life adaptational requirements appears to be reasonably well established, but additional evaluation of the specificity issue is needed.

Given an association between negative affect and cortisol excretion, stress models typically would favor the interpretation that affect influences hormonal state. This inference is consistent with the observed correlations, but other plausible interpretations exist. For example, abnormalities in cortisol metabolism have been linked to clinical depression (Berger, Doerr, Lund, Bronisch, & von Zerssen, 1982; Carroll, et al., 1980). It may be that adapting to stressful conditions produces high cortisol excretion in biologically predisposed individuals who experience depression and other negative affects as a consequence of this excretion. Negative affect then may influence perceptions of the situation in ways that account for weak associations to perceived stress. This alternative explanation of the major findings in this study illustrates the need for detailed studies of affect-cortisol dynamics in normal individuals under stressful conditions to provide a better basis for any causal interpretation of the findings. In the context of these considerations, it is worth noting that the mean scores for the various mood measures indicated low levels of negative affect. The importance of stressful conditions for demonstrating affect-cortisol associations, therefore, may be simply that demanding circumstances are required to elicit sufficient negative affect to influence cortisol excretion or vice versa.

The negative findings for personality replicated Ballenger, et al. (1983), but contrast with Herbert, et al.'s (1986) report of a modest positive association between cortisol and neuroticism. On the average, these studies of normal individuals suggest that neuroticism and extraversion are weak predictors of cortisol excretion. Future studies may have greater success if the focus shifts from general personality dimensions to specific personality determinants of affective reactions to stress. These determinants might include long-term trends in expression of specific emotions which are subcomponents of the neuroticism dimension. Another possibility is coping and defense mechanisms which influence stress reactions and are largely independent of the major personality dimensions (McCrae & Costa, 1986). Here again, future studies should assess mood at the time of study to test the possibility that any observed associations between cortisol excretion and personality arise from the effects of personality on emotional status.

The overall conclusion from this study emphasizes those results that are part of a growing body of evidence that individual differences in affect are reliably related to individual differences in cortisol excretion when normal individuals are studied during periods of significant adaptational demands. These findings are consistent with psychobiological models that assume that stress and personality are important primarily as determinants of emotional status (e.g., Thoits, 1984), but further studies along the lines suggested above should be fruitful for understanding mind-body interrelations which may affect health.

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Cortisol excretion is [illegible] but recent studies of normal [illegible] strate significant correlations between [illegible] personality. Psychological [illegible] military recruits during basic [illegible] obtained when normal individuals were [illegible] Negative [illegible] mood, predicted higher cortisol excretion [illegible] significantly predict cortisol excretion [illegible] who felt highly pressured [illegible] conclusion is that cortisol [illegible] tions which demand substantial [illegible] needed to determine the direction [illegible] role of personality and perceived stress [illegible]

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